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The Historic Timber Structure Conservation of Madrasah Idrisiah Building, Kuala Kangsar, Perak

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Abstract - Madrasah Idrisiah is the first royal religious School in Perak. The main building is a double storey timber structure and was built in the year 1917. In 2017, through the allocation from the National Heritage Department of Malaysia, the main building of the Madrasah Idrisiah has been involved with building conservation works. The building has a timber structure defect such as deterioration due to moisture problems, insect attack, fungal attack, and improper repair works. The conservation of timber structures involves repair of beams, column, shafts and roof structures. This paper is discussing the methods and techniques for conservation work on a historic timber structure which involve the main block of Madrasah Idrisiah. The proposed conservation method is the minimal intervention and the main aims are to restore and consolidate the existing timber structure. The proposed conservation method is being based on historic building conservation guideline by Malaysia National Heritage Department.
Keywords - Conservation, Timber Properties, Timber Repair Work.

1 INTRODUCTION

Madrasah Idrisiah is the first religious school in Perak. It was built in 1917 during the reign of Sultan Iskandar Qaddasallah, son of Sultan Idris II Mursyidul 'Adzam Shah. The building is built on a land nearly 3 acres and is opposite to Ubudiah Mosque, Kuala Kangsar. The main building is a two-storey timber structure measuring 32 feet x 222 feet with an estimated floor area of 6,796 square feet. Originally, the first floor of the building was used as a student accommodation while school activities were carried out on the ground floor. This symmetrical building is built with an open corridor around it. The corridor is supported by timber pillars standing on the masonry stump on the ground floor. The center part of the building is built strangled out to front side is the porch where the school office is located on the first floor. The main building and the school site itself are almost 100 years old and has been some further development throughout that period as shown in figure 1. Construction of additional buildings began in 1985 during the late Sultan of Perak, Sultan Azlan Shah.

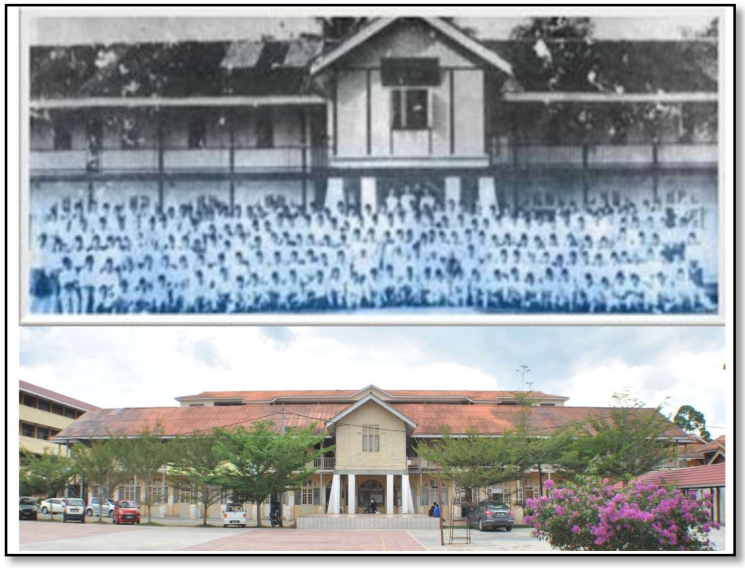

Figure 1: Top: Archive picture of Madrasah Idrisiah building with the students (Source: Madrasah Idrisiah) and below: Front view of Madrasah Idrisiah right before the conservation work started in 2017 (Source: Conservator)

2 INTRODUCTION TO TIMBER PROPERTIES

Mechanical properties or strength of timber is closely related to the density and structure of the anatomy of the wood cells (Walker, 1993). These cells are complex natural builds consists of a mixture of polymer and cellulose. The structure of the timber cells provides 16 times more natural strength than the same mass of iron (Malaysian Timber Council, 2010). The construction of this timber anatomy also affects the physical properties and strength of a timber species. Therefore, certain timber species are only applicable to certain uses. This has been proven by the history and the wisdom of traditional carpenters in a Malay traditional building which only uses certain species because of its resistance, such as chengal (*Neobalanocarpus héimii*), is the most popular species for the construction of home structures. Other chengal species such as chengal mas (*Hopea odorata*) and chengal batu (*Hopea ferrea*) (Killmann et al., 1994). However, there are many other timber species that have a variety of specific strengths for construction work. Timber strength is associated with a direction of force or impact on it. A piece of timber is easy to fail or crack due to the force parallel to the grain orientation, instead the timber is stronger and holds if the direction of the load is perpendicular to its grain orientation. Basically, the tree anatomy is divided into two main parts that are processed into sawn timber in the sawmill where sapwood which softer and brighter colors; and the heartwood is a harder and darker located at the core of the log. Both of it are in the same logs. The Malays have long been using heartwood for a variety of uses including handcraft making. Science has proven that the heartwood part is stronger and more durable compared to sapwood part (Walker, 1993). In the Madrasah Idrisiah conservation project, the conservator recommends not to use new timber components that include both heartwood and sapwood in the single workpiece to ensure its durability and strength. Besides that, timber components with knots are avoided because it is a critical point to fracture due to its curly grain structure.

Timber has the ability to absorb water directly and moisture from the surrounding air. When its expose in the dry surrounding, the timber will release the moisture through the evaporation process. Absorbing the moisture and evaporation process makes the timber swelling and shrinking, thus changing its size. This is called timber movement (Walker, 1993). The 'movement' of the timber cannot be seen with the naked eye, but enough to bring an affect to the quality of construction. Furthermore, timber decaying agents are a fungal attack which is also due to the moisture in the timber. Timber pests such as termites and other insects are more likely to attack the timber at certain moisture levels. In conserving the timber structures of Madrasah Idrisiah most of the timber defects are due to exposure to moisture in long derelict period. The conservators and contractors involved suggested that new timber should be kept in a dry place for two weeks to ensure the timber achieve the 'equilibrium moisture content' (EMC) level before being used for restoration. This is to avoid the timber movement occurred after the restoration works completed, which can affect the quality of workmanship.

3 THE CONSERVATION OF TIMBER STRUCTURE

Conservation of historic buildings involving timber materials, especially building structures, is essential to conserve not only in terms of heritage, but in terms of technical and mechanical that ensures the building is sturdy and sustained for the future. For conservation work involving historical or heritage timber structure, it is necessary to comply with standards and the principles of heritage conservation. For the restoration of traditional buildings, the timber that to be replaced must be from the same species or at least equivalent in properties as the original timber. That is also the same goes for its construction method (ICOMOS, 1999). However, if the traditional techniques were difficult or will cause new damage on other components involved, any modern technique for conservation and construction can be used as an alternative where its effectiveness can be read by scientific data and can be proven by experience (Article 10: Venice Charter), (ICOMOS, 1964). The most important thing in the conservation project, which using timber material is documenting every detail of the repair works, whether a new replacement, timber jointing, changes in construction techniques including the use of new materials/technologies and material sources. According to Brown (2013), the documentation produced through the construction drawings become an important historical record for a restored building, it can be a reference for future conservation work hereafter. The conservation of the timber structure of this building refers to the National Heritage Department's Building Conservation Guidelines (JWN, 2017). The conservator has come out with

proposed timber remedies techniques which accommodate with the guidelines through 'method statement' prior the restoration. 'Method statement' is a standard report that explains the existing condition of the building parts, the cause of the defect, the method of recording the existing material, the proposed restoration method with diagram and the necessary precaution. Prior to the timber structure conservation work, the identification of the timber types according to the components was carried out by the Malaysian Industry Board (MTIB). There are three main types of timber used, namely Merbau (*Intsia palembanica*), Meranti Merah (*Shorea Spp*.) and Nyatoh (*Palaquium spp*.). Merbau timber is used for structure building, while Meranti Merah and Nyatoh are widely used for door components, windows and floor boards.

In the Madrasah Idrisiah conservation project, the researcher identified and categorize the timber structure repair works as below:

i. Restoration works which include:
   a. Cut and Joint
   b. Duplication
   c. Modification
ii. Consolidation by steel reinforcement
iii. Consolidation by transfering the loads to additional of new structure

3.1 The Timber Structure Restoration by 'Cut and Joint' Technique

A total of 11 pillars was identified to have decayed on the jointing between masonry stumps. The cause of decaying is due to humidity and pest attack. The tenon of the pillars on stumps has been decayed and lost. See Figure 2. The consequence of this decaying causes the pillars to leaning and unstable to support the beams and joists of the first floor corridor.

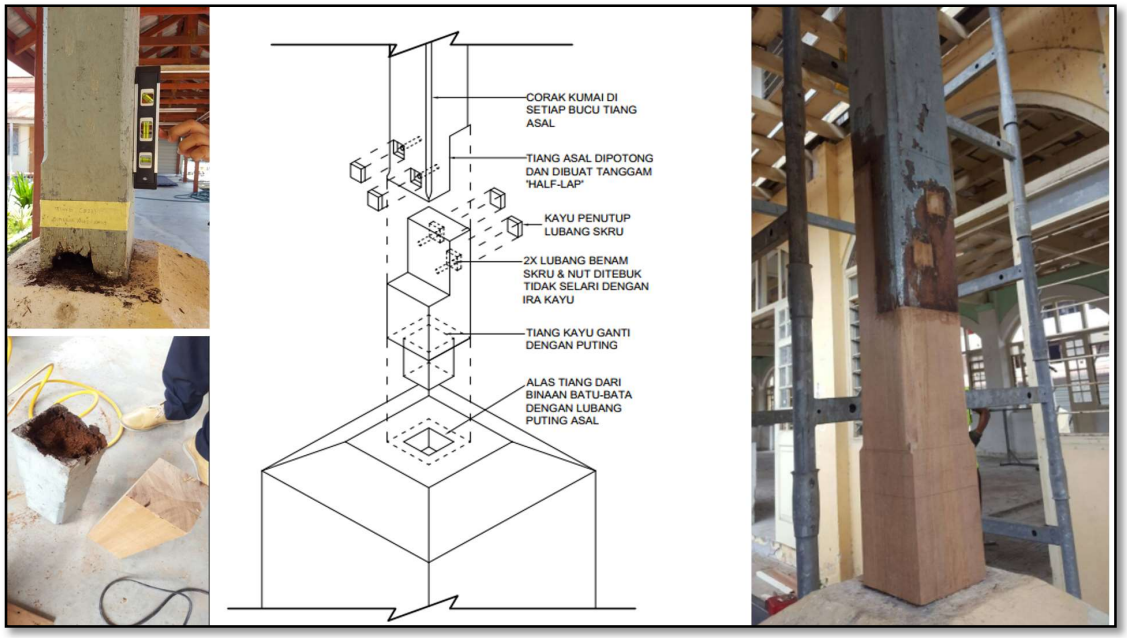

Figure 2: Timber pillar defect due to deterioration. Right; timber pillars have been fragile due to pest attack. Middle; Exploded view on 'cut and joint' method and left; Complete timber pillar restoration

The pillars that have been cut is replaced with the new component that is duplicated according to the original, which is same properties in terms of strength and size. The new timber is needed to be dry enough and free from defects such as cracks and knots. The new pair of timber pillars are the same as the original timber species or at least from the species that most closely in mechanical properties. The original species of timber pillars used for this building are from Merbau (*Intsia palembanica*) which is classified as a hardwood (Malaysian Timber Council, 2009) (Malaysian Timber Industry Board, 2017). The jointing between the original timber pillar and the new ones by using the 'half-lap' jointing and tied with screws

and nuts, see figure 3. The screw holes need to be drilled not parallel to the timber grain (diagonal) to prevent split pole along the grain line. The screw and nut connections are concealed and patched with the same timber species with original poles. The profile pattern on the new pillar edgings is duplicated to the original pillars. This purpose is for getting uniformity in design. At the last stage, after the glue dried, the surface of the jointing is smoothen by planing and sanding the surface. The gap between the timber and the masonry stump will be inserted with waterproof glue to prevent the absorption of water in the future.

3.2 Duplication According the Original Timber Component

Most of the roof trusses of this building are in good condition except one of the kingpost found deteriorated suspected of roof leakage which has exposed the component with moisture. Kingpost is one of the timber members of the roof structure that stand in the middle of the truss which holds the ridge (see figure 3). All the roof truss members are tightened with its special ironmongeries. According to the 'method statement' prepared, the deteriorated kingpost should be detached from its members in order to conduct the duplication work. All the connected roof truss members are clamped accordingly before the removing deteriorated kingpost and replacing with new. The removed original kingpost is measured precisely to duplicate the new kingpost. The duplication work is not conducted on-site due to the custom made work. The new kingpost is made from the same grade of timber to remain the structure authenticity.

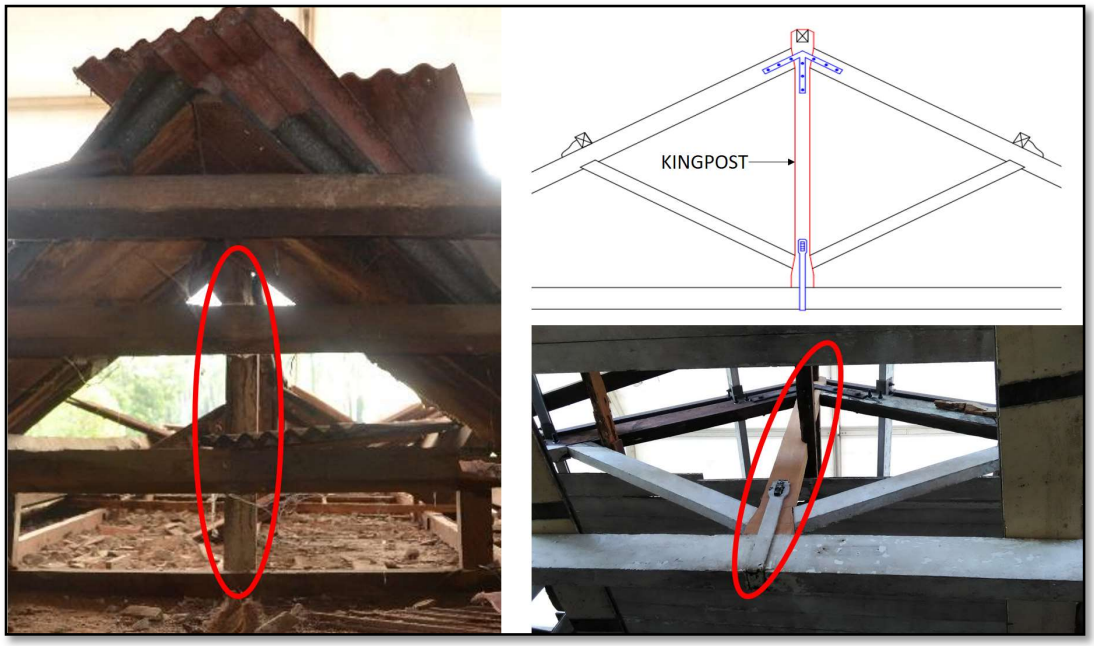

Figure 3: Left; Deteriorated kingpost. Right Top; Kingpost position on roof truss members. Right below; Restored Roof truss with duplicated kingpost tighten with original ironmongeries.

3.3 Modification of Jointing Technique

Any timber structure is constructed according to its special techniques. Each structural member has its sequence during the construction (Brown, 2013). Generally, in any conservation work, the minimal intervention is the priority due to the sensitive old building condition. In Madrasah Idrisiah case where the building construction is complex. Some jointing is using metal nails. This building is designed not to be dismantled or reallocate as most traditional timber houses in Malaysia (Yuan, 2002). It can be considered as permanent structure and it is impossible to dismantle part by part to reach the defected component. One of the beams in the Madrasah building has been decayed on both ends of the connection. The 'tenon and mortise' joints have serious decay on both of the beam ends (tenon). Whereas, the beam located between the two pillars is attached to the mortise on the pillars. Both pillars are still in good condition and stand firm. Technically, this beam replacement process needs to shift one of these pillars. These pillars are also attached together with roof and floor systems. In order to minimize intervention on the building as advised by ICOMOS and National Heritage Department (2017), the conservator has come

out with modification on the replacing beam without obviously change its original appearance. Special jointing on the middle of the beam has been designed in order to not shifting the existing pillars as shown in the figure 4 below:

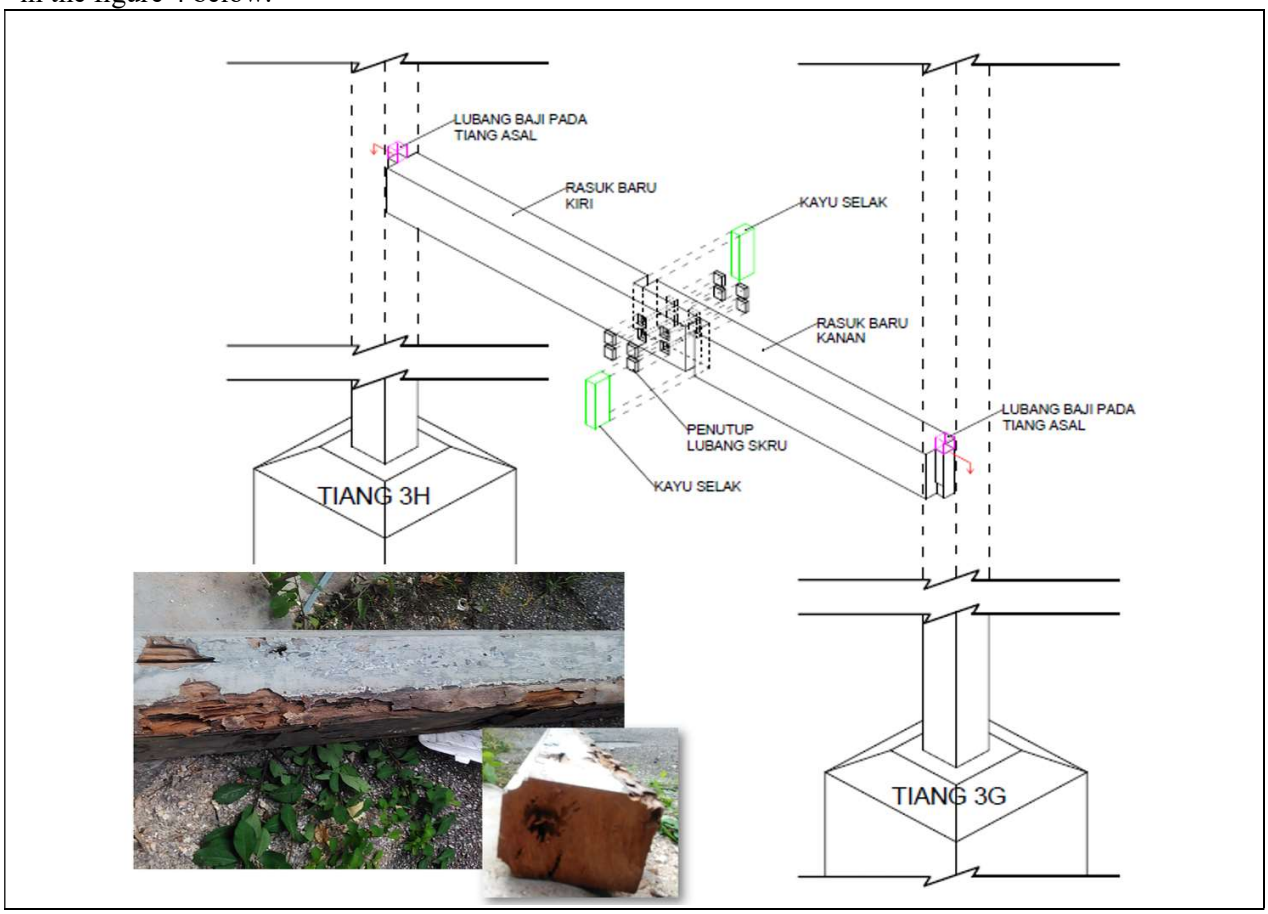

Figure 4: Diagram shows the new beam with proposed jointing in the middle in order to minimize the intervention on both pillars during restoration work. The left-below pictures show the decayed on the original beam.

Therefore, in certain cases, the problematic timber structure should be restored on-site without dismantling the other structural members which connected. Dismantling and removing any of the existing components will bring risks to new damage. The modification of the jointing or component design itself should be necessary due to some timber restoration process are differ from the original installation process.

3.4 Reinforcement on the deteriorated Timber Beams.

A part of the timber defects that due to moisture, there are pest attacks, timber aging problems and the deterioration of durability. There is a timber defect due to their natural growth, such as splits and crack on timber knots (spiral grain) or wavy grain, interlocking grain, hollow timber and high dense timber. The timbers that have natural defects, should not be used in construction. There is a beam in the Madrasah building that has experienced natural defect caused fractures on knots. The timber beam needs to be preserved to ensure that the structure does not deteriorate and less strength to bear the loads from the top floor.

Figure 5: The beam number 18 has cracked due to timber knots. There are knots and crack that suspected can cause the beam to bend and will eventually break. Right: example of timber knots (https://www.woodworkingnetwork.com/best-practices-guide, 2017)

The proposed conservation method is by straightening and raising beam no. 18 to its original position with an additional steel plate. This method is intended to reinforce the first floor structure by using a custom steel plate. For security purposes and structural strengthening, the temporary steel prop is installed to transfer the beam's loads directly to the ground. The dropped beam is slowly jacked up until reach to its original position without damaging the other original components. The temporary steel prop is remain in use until the iron plate installation is completed. The surface of the beam is slightly cut and planed according to the shape of the steel plate. The width and length of the steel plate must have covered the cracked area. The holes are drilled through the beam matched with holes on the custom steel plate. The holes are avoided from being drilled on critical parts (cracks and knots). The steel plate shapes and thicknesses, as well as the size of the screws, are according to the engineer's recommendations. The steel plate should have located above the masonry column to help send the loads directly through it. After the installation of the steel plate, the plywood is cut according to the same shape is used to cover the exposed plate screws. The direction of the woodgrain of the plywood board should be in line with the original timber beam grain direction. Plywood attached with glue and wood putty/filler before applying the proposed finishing.

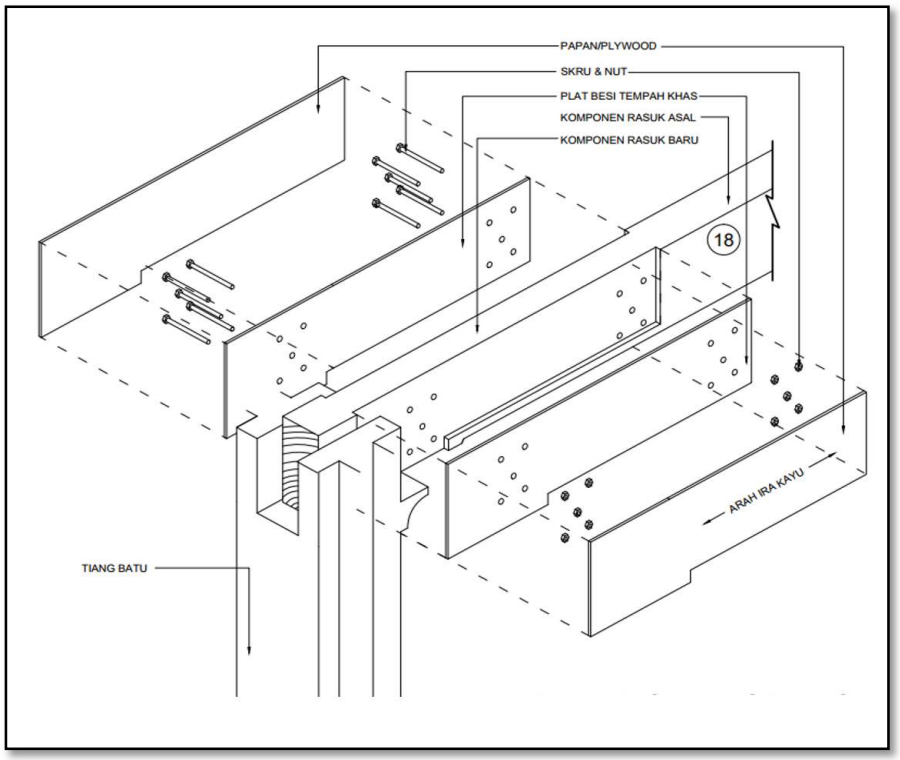

Figure 6: The Installation method of steel plate on beam no.18

3.5 Transferring The Loads by Additional Structural Members

A beam in the building structure transfers its load laterally along its length to its supports which mostly are columns. Due to the nonconcurrent pattern of forces, a beam is subject to bending (Ching, 2014). One of the timber beam Madrasah Idrsiah had fractured due to 'bending stress'. This occurs due to 1 from 3 columns that support the beam which is in the middle had failed to support it loads due to natural ground movement. While in the meantime, there are 'live loads' stored above it during the roof repair work. Removing the fractured beam will give serious intervention to the structure of the building. The conservator of the project has taken an approach to remain the fractured beam since the crack effect can be vanished by the putty and finishing. However, the loads which supported by the fractured beam need to be transferred to the new structure. The new structure should not obviously change the original appearance of the building in order to remain the design authenticity. The conservator had proposed steel I-beam as the additional structure member. The proposed position of the additional I-beam is almost concealed from the outside view (see figure 7). The additional I-beam function is to support the loads from the floor joists that supported by the existing timber beams before. The I-beam directly transfer the loads to both masonry columns and the middle timber pillar.

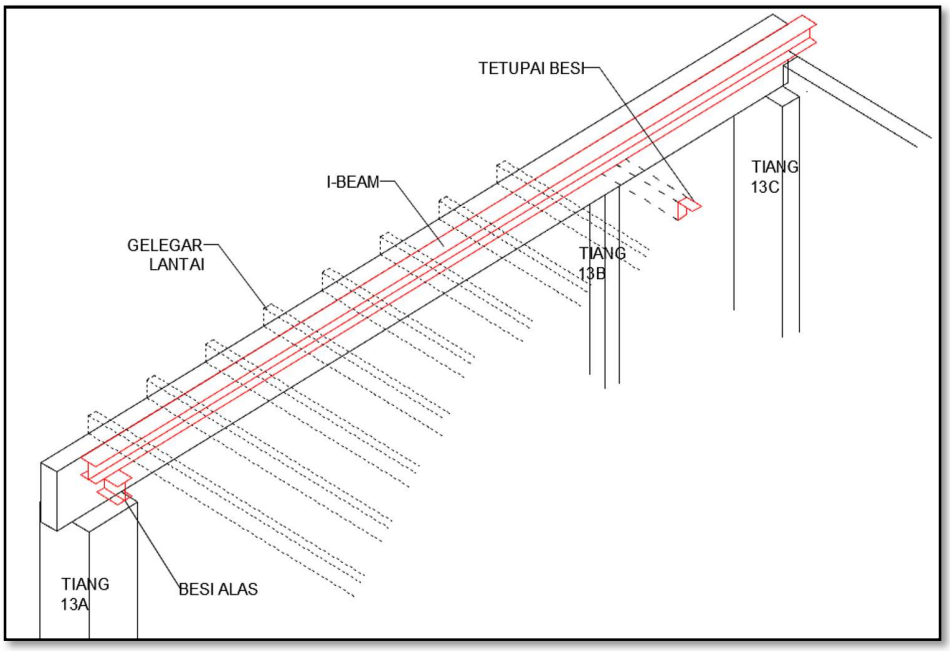

Figure 7: The new I-beam takes over the original timber beam by transferring the floor joist loads. The original exposed timber beam is preserved for aesthetic authenticity.

4.0 SUMMARY AND DISCUSSION

Each timber species has its own natural properties. Understanding this is a pre-requisite for working with this material which is able to make the right decision on every proposed repair work. The completed timber works or restored can show a specific response after a certain period. From this response, it can be diaognized to conclude the mistake of the process that has been made and timber also will show an obvious effect if it is not treated properly. This is likely due to negligence during work and lack of knowledge about timber (Zwerger, 2012). To identify the timber damage is not just by looking at the physical defect and symptom, but requires an investigation on the nature of the material. Early diagnosing on timber defects and timber expert advice are the factors that priorily need before the timber building conservation work started. However, in Madrasah Idrisiah, through recording procedures and documentation before timber-work begins, the conservator has first conducted an investigation into the timber properties. The method of knocking with hammer on timber components has identified the degree of damage and the distance of the timber that is still in good density condition. Through this technique, the restoration that spell in the scope of work earlier, which replace the whole pillar (such as case 3.1) has been changed to 'cut and joint' method. This method had saved more original timber pillars of the building and meet the principle of conservation of historic buildings by replacing just a minimal critical portion of the component rather than full replacement. Referring to international conservation practices, the timber structure of the historic building is referred to as the historical timber structure. The timber structure includes construction works or craftsmanship and constructive craftsman is part of explaining the heritage of the building (Larsen and Marstein, 2000). Therefore, each conservation project where involve timber-work should refer to specific guidelines. The knowledge of timber helps to determine which method or technique should be used in repairing work. This is to ensure the restoration works such as old and new timber jointing is not just for cosmetic appearance, but more important are the durability and lifespan after being conserved. Additionally, thorough diagnose on the defects and causes of damage should be a part of scope in timber restoration, thereby appropriate techniques for conserving and treatments can be determined. It is hoped that in the future, the conservation work on historic timber buildings in Malaysia will have a special guideline for conservation works as well as masonry building. The modification, reinforcement of other material used in conservation are for the sake of safeguarding and prolong the building life. The conservator must try as best possible to not change the esthetic and the original appearance of the historic building. In Madrasah Idrisiah conservation, any new additional are marked and recorded to differentiate between the original design for future reference.

5.0 ACKNOWLEDGMENT

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